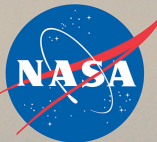


# The Orion Pad Abort 1 (PA-1) Flight Test: A Propulsion Success

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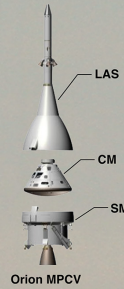
## Human Spaceflight and the Orion MPCV

- The Constellation program Ares I architecture
  - Included the Orion Crew Exploration Vehicle (CEV)
  - Planned for utilization after the retirement of the Space Shuttle
  - Constellation program was cancelled in 2010
- The Space Launch System (SLS) architecture
  - Includes the Orion Multi-Purpose Crew Vehicle (MPCV)
  - Transport humans beyond low-Earth orbit (LEO)
  - Provide a transport capability to the International Space Station (ISS), as a backup for commercially developed vehicles



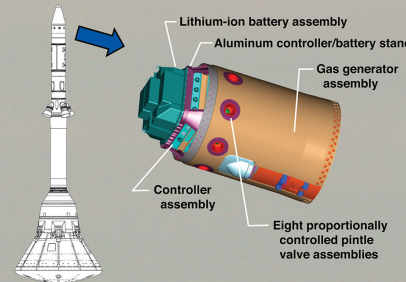
Space Launch System

- The Orion MPCV includes:
  - Launch Abort System (LAS)
  - Crew Module (CM)
  - Service Module (SM)
- The Orion Abort Flight Test (AFT) project:
  - Purpose: To conduct a series of flight tests in several launch abort scenarios to certify Orion LAS capability
  - Responsibility: The Orion Flight Test Office, at NASA JSC
  - The Orion PA-1 flight-test vehicle integration and operations effort was led by the NASA Dryden Flight Research Center (now the NASA Armstrong Flight Research Center)



Orion MPCV

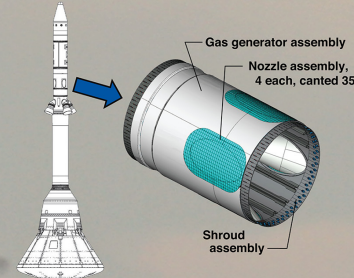
## Orion PA-1 LAS ACM Overview



LAS ACM Demonstration Motor 2 (DM-2)

- Purpose: Provide pitch and yaw control to optimize the LAV abort trajectory
  - Boost phase: Utilized for LAV directional control and stabilization
  - Sustain phase: Utilized to pitch-over and reorient the LAV
  - PA-1 LAS ACM maximum thrust: ~7,000 lbf
  - PA-1 LAS ACM action time: ~35 seconds
- Developed by: Alliant Techsystems, Inc. (ATK) in Elkton, Maryland

## Orion PA-1 LAS JM Overview



- Purpose: Provide the thrust force required to jettison the LAS from the Orion CM, in both the abort and nominal flight scenarios
  - Abort scenario: Utilized after the AM and ACM have performed their functions
  - Nominal scenario: Utilized with fully loaded AM and ACM propellant
  - PA-1 LAS JM nominal maximum thrust: ~44,000 lbf
  - PA-1 LAS JM action time: ~2 seconds
- Developed by: Aerojet in Sacramento, California (now part of Aerojet Rocketdyne)

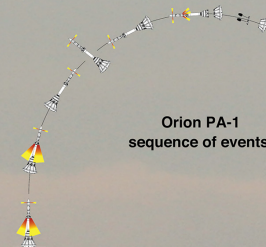


LAS JM DM-2

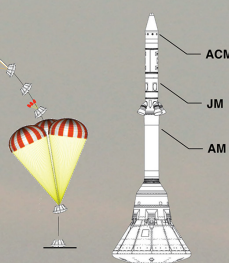
## Propulsion on the Orion PA-1 Vehicle



Apollo 11 during launch



Orion PA-1 sequence of events



Orion PA-1 LAV

- The Orion LAS includes several subsystems, three of which are solid rocket motors:
  - Attitude Control Motor (ACM)
  - Jettison Motor (JM)
  - Abort Motor (AM)

## Ensuring Flight Safety

- The Orion LAS provides an abort capability in the unlikely event of a booster failure
  - Abort capability exists while on the launch pad or during mission vehicle ascent
- The architecture of any human-rated launch vehicle and spacecraft will always require the greatest level of safety
- The Orion PA-1 Flight Test Vehicle demonstrated an abort capability from the launch pad
  - Flight test occurred on May 6, 2010 at the White Sands Missile Range, in New Mexico
  - All three motors successfully demonstrated their required functions during the PA-1 flight

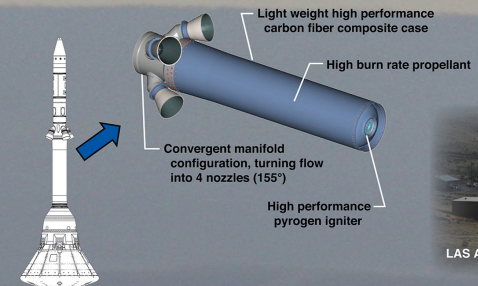


Orion PA-1 Launch Team

- Future flight-testing (beyond PA-1) will ensure LAS capability on the Orion MPCV for the SLS
- More detailed information on propulsion for the Orion AFT project has been published:
  - “Executive Summary of Propulsion on the Orion Abort Flight-Test Vehicles,” AIAA 2012-3891

## Orion PA-1 LAS AM Overview

- Purpose: Provide the thrust force necessary to propel the LAV safely away from a failed booster
  - Thrust is balanced between the desire to escape quickly and the human tolerance for acceleration
  - PA-1 LAS AM nominal maximum thrust: ~500,000 lbf
  - PA-1 LAS AM action time: ~7 seconds
- Developed by: ATK in Utah



LAS AM Static Test 1 (ST-1)